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MELBOURNE, VICTORIA

Aircraft Structures Technical Memorandum 504

ADDITIONS AND CORRECTIONS TO "SUPER"
A PROGRAM FOR CALCULATING STEADY AND
OSCILLATORY SUPERSONIC FLOW
OVER A THIN WING, TAIL PLANE AND FIN

by

I.H. GRUNDY

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SUMMARY

This paper describes changes to the computer program "SUPER", which correct errors identified in the previous version of the program, and enable the calculation of generalised forces. Tables of generalised forces, calculated using "SUPER" and other programs, are presented for a standard AGARD configuration.

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CONTENTS

1. INTRODUCTION

Recently, a computer program (SUPER) has been developed for the calculation of linearised steady and oscillatory supersonic flow over a configuration consisting of a coplanar wing and tail in association with a vertical fin [1]. This program implements an explicit finite difference scheme based on [2], extending and correcting work done previously at ARL ([3]). The primary motivation for this work is to enable the calculation of unsteady aerodynamic derivatives, i.e. generalised forces, for insertion into aeroelastic mathematical models.

In SUPER, the velocity potential is calculated throughout the flow field, and both the potential and pressure are calculated on the lifting surfaces. However, the program stops short of calculating generalised forces from these quantities.

The purpose of this paper is to list and correct a number of errors identified in the last version of SUPER (i.e. in [1]), and to describe the modifications to SUPER which enable the calculation of the required generalised forces. Generalised forces calculated using SUPER are compared with the results of other solution schemes for a number of standard configurations.

2. REVISED DESCRIPTION OF PROGRAM

Only significant changes to SUPER will be described in this section, e.g. changes which alter the input to or output from the program, or which correct errors in the program.

The old "wing functions", "tail functions" and "fin functions" parameters IPAR, JPAR and KPAR respectively have been replaced by a single "forcing mode" number IFM. The last version of SUPER could calculate the potential and pressure for a regular sequence of Mach numbers and reduced frequencies, and only for a single "forcing mode". Modifications have now been made to allow the program to handle a list of Mach numbers, reduced frequencies and "forcing modes". The "forcing modes" have been further subdivided into symmetric and antisymmetric groups, so that the generalised forces for the two groups can be calculated and displayed separately.

Calculation of the generalised forces has naturally led to additions and modifications to the code. There are now three new subroutines WINGFORCES, TAILFORCES and FINFORCES, in which contributions to the generalised forces are calculated. Output from these subroutines is collated in a new array GENFOR which contains the generalised forces from each mode/Mach number/frequency run. The symmetric and antisymmetric results are later extracted from GENFOR for tabulation.

The subroutines SOLVE1 and SOLVE2 have been changed to prevent discrepancies at the leading and trailing edges between these routines and the output routines OPUT1 and OPUT2. These changes entail working with the indices (i, j, k) of each point, as in OPUT1 and OPUT2, instead of the cartesian co-ordinates (x, y, z), when implementing boundary conditions.

Two errors were discovered and corrected in SOLVE1 and SOLVE2. In the program listing on page 84 of [1] the statement

```
Z1=FLOAT(K-1)/DD
```

appears. The correct line is

```
Z1=FLOAT(K-1)/DD/2.0 .
```

Tests using the standard AGARD planform (see [5]) revealed this error, which was not detected in [1] because the code was tested only for a rectangular fin (for which the leading and trailing edge positions are independent of the vertical coordinate Z1).

The second error involved setting the contribution from the derivative boundary condition points to zero when one or both of these points lay off the lifting surface (in a wake or diaphragm region) immediately ahead of a solution point lying on the surface. These normal derivatives are in general non-zero and unknown in advance. A quick and consistent solution to this problem was found to be evaluation of the derivatives as if the points were actually on the lifting surface.

With the above modifications, input to the program has changed correspondingly. A new value of the output parameter IOUT has been added (IOUT=4) to enable the generalised forces to be printed without the accompanying pressure and/or potential output. As mentioned above, the variables IPAR, JPAR and KPAR have been replaced by IFM.

Multiple "forcing modes", Mach numbers and reduced frequencies are handled by writing the number of each quantity on one line, and the list of values in free format on the line, or lines below.

The "displacement modes" to be considered are separated according to their spanwise symmetry. The spanwise symmetric modes, of which there are NSM, are numbered first, followed by the NAM antisymmetric modes, which are numbered NSM+1 to NSM+NAM. Each "forcing mode" must belong to one of these two subsets, so that its symmetry is clear to the program.

Finally, the streamwise grid spacing has been replaced by the spanwise grid spacing as input to the program. (One can easily be calculated from the other.)

The new input file takes the form

```
1           1 if flow unsteady, 2 if flow steady.
2           Output: 1 press., 2 pot., 3 both, 4 gen. forces
1           Width : 1 for 80 char. wide output, 2 for 132 char..
6           No. of dec. places in output, must be in range 4-8.
0.05        Spanwise grid step size.
1.0         Wing semi span length.
1.0         Tail semi span length.
0.0         Lowest vertical point of fin.
1.2         Highest vertical point of fin.
2           Number of Mach no.s
1.2 3.0     Mach numbers
3           Number of Red. freq.
1.5 0.5 1.0 Reduced frequencies
```

```
0           No. of symm. displ. modes (labelled 1...NSM)
4           No. of antisymm. displ. modes (NSM+1...NSM+NAM)
2           Number of forcing modes (NFM)
1 3         Forcing modes.
```

The separation of the modes into symmetric and antisymmetric groups has also led to necessary changes in the mode shape subroutines. For example, corresponding to the input data file above, these subroutines take the form shown in Appendix 1.

The first mode shape in each subroutine, corresponding to label 1, refers to the shape of the wing for the steady flow calculation. Subsequent labels refer to the unsteady modes, e.g. label 2 corresponds to unsteady mode 1. Looking "horizontally" across the mode shape subroutines, it can be seen that mode 1 is purely a wing mode (twist) since there are zeros in the equivalent positions in the tail and fin subroutines. Similarly mode 2 is a pure tail mode (pitch), and modes 3 and 4 are purely fin modes (bending and twist respectively). No doubt each subroutine could be shortened by eliminating all but one of the zero modes; however this would contribute nothing to the clarity of the code.

3. CALCULATION OF GENERALISED FORCES

SUPER computes the potential and pressure on each lifting surface. There are two approaches to the calculation of generalised forces from these quantities. The first of these involves direct integration of pressure multiplied by mode shape over the whole surface (which to fix ideas we will take here to be the wing). The generalised force Q_{ij} in the ith mode of oscillation resulting from harmonic oscillation in the jth mode is given by

$$Q_{ij} = -\frac{1}{2\ell^3}\int_{-\ell}^{\ell}\int_{x_{le}(y)}^{x_{te}(y)} \Delta C_{pj}(x,y) f_i(x,y)\,dx\,dy. \tag{2.1}$$

where ℓ is the wing semi-span,

$$\Delta C_{pj}(x,y) = -2(\Delta\phi_{jx}(x,y) + i\omega\Delta\phi_j(x,y)),$$

is the difference in pressure coefficient between the lower and upper surfaces of the wing resulting from oscillation in mode j (the jth "forcing mode"), $f_i(x,y)$ is the ith "displacement mode" and ω is the reduced frequency. The above formula is equivalent to that given in [4]. Similar formulae apply for the tail and fin.

This straightforward method involves use of both the reduced potential ϕ, (actually ϕ_0 in [1]), and its streamwise derivative ϕ_x. There are, however, significant problems associated with the use of ϕ_x, and these are described below.

There is a fundamental difference between the behaviour of the pressure distribution at a subsonic leading edge, where it has a square-root singularity and at a supersonic leading edge, where it remains bounded. For the generalised force results to be accurate, the integration scheme must determine whether a singularity exists and model it correctly.

This is particularly difficult because, in general, the streamwise potential contains jagged oscillations. These oscillations arise because the geometry of the leading edge of the wing is not modelled exactly, appearing to the program to be changing in a steplike manner. A pair of Mach lines emanate from each of these step changes, and sharp changes occur in the streamwise potential as each line is crossed. On differentiation these oscillations are magnified, swamping the true behaviour of the pressure at the leading edge, and making it nearly impossible to integrate accurately. As a result, the direct integration method can only confidently be applied to supersonic leading edges.

The effect of the jagged leading edge has been noted previously (e.g. in [12]) in conjunction with the Mach box method, and the solution has been to bypass the need for the pressure by carrying out a preliminary integration by parts. This gives the generalised force integrals in terms of the potential only. To be specific, it leads to the formula

$$
\begin{aligned}
Q_{ij} =& \frac{1}{\ell^3}\int_{-\ell}^{\ell}\Big[\Delta\phi_j(x,y)f_i(x,y)\Big]_{x_{le}(y)}^{x_{te}(y)}dy \\
&-\frac{1}{\ell^3}\int_{-\ell}^{\ell}\int_{x_{le}(y)}^{x_{te}(y)}\Delta\phi_j(x,y)\Big[f_{ix}(x,y)-i\omega f_i(x,y)\Big]dxdy.
\end{aligned}
\tag{2.1}
$$

The advantage here is that since ϕ_j is always bounded, it requires no special treatment (in the surface integral at least). One possible disadvantage of this method is that it involves line integration at both the leading and trailing edges and these could conceivably be sensitive to the streamwise oscillations in ϕ. However, experience shows that the effect of the oscillations is reasonably small in the line integration.

As before, the main problem lies with subsonic leading edges, i.e. regions in which ϕ_j changes rapidly. It was found that the resolution at the leading edge was not always adequate to capture the full effect of the singularity in slope. This was remedied by evaluating ϕ_j in the line integral at a position one grid point upstream of the leading edge. The philosophy here is that the potential changes relatively slowly ahead of the lifting surface, so the error in estimating a rapid change in ϕ_j near the leading edge should be small.

For the wing and fin, the above solution can always be applied because the potential is identically zero in the plane of, and ahead of, the wing or fin. For a tail immersed in the wake, this solution should apply as long as the reduced frequency, which controls the frequency of oscillation of ϕ in the wake, is not too large.

In the latest version of SUPER we implement the second method described above for the calculation of generalised forces. All integrals are performed using the trapezoidal rule in one and two dimensions. The results presented in Section 4 show reasonable convergence properties with decreasing grid size.

4. RESULTS AND DISCUSSION

Comparison has been made between the output from SUPER and that from a number of other methods, namely

a. the Mach box method, [6] and [7],

b. the potential gradient method, [8] and [9] (improved),

c. the doublet point method, [10], and

d. the harmonic gradient method, [11],

for a number of well known interference configurations. In addition, results are also given from [2] in which the present finite difference scheme first appeared.

It should be noted here that [4] provides an exhaustive list of generalised force results for a number of wing-only planforms. However, as agreement with those results is quite good, only those results for the more difficult cases of coplanar wing and tail, with and without vertical fin interference are presented here. As mentioned above, the test cases used are largely defined in the AGARD supplement [5] (from which Figure 1 is reproduced), and many of the results quoted here appear in that reference. Forty spanwise grid points were tried as in [2], and gave reasonable results. However, it was decided to generate the present results with sixty spanwise points, as this led (naturally) to better agreement, especially at $M = 3.0$.

Tables 1 to 3b show generalised forces calculated for the coplanar wing and tail configuration shown in Figure 1 at Mach numbers 1.2, 1.356, and 3.0, and reduced frequencies 0.0 and 1.5. The results of the present method (which here and below we will refer to as [1]) are compared with those of [2], [6], [7], [8] and [10]. The mode shapes here are

	1.	Wing Twist	$z = y(x - 2.25\lvert y\rvert - 0.85)$,
	2.	Wing Bending	$z = y\lvert y\rvert$,
	3.	Tail Roll	$z = y$,
and	4.	Tail Pitch	$z = (x - 3.35)\,\mathrm{sgn}\,(y)$.

There is good agreement here between the various codes, except that the present method tends to underestimate the magnitude of the generalised forces by a small amount.

Table 4 shows generalised forces obtained from the present program for a coplanar wing, tail and vertical fin at Mach number 3.0. Results from the present method for this configuration are compared to results from [8] and [9] for the following modes:

	1.	Wing Twist	$z = y(x - 2.25\lvert y\rvert - 0.85)$,
	2.	Tail Pitch	$z = (x - 3.35)\,\mathrm{sgn}\,(y)$,
	3.	Fin Bending	$y = z^2$,
and	4.	Fin Twist	$y = z(x - 0.875z - 3.0)$.

The results of [9] appear (as expected) to be more reliable than those of [8]. Certainly, there is better agreement in the orders of magnitude of the terms between [1] and [9]. Notice, however, that there are some significant differences in

sign and magnitude for the modes involving perpendicular surfaces e.g. Q_{31} (fin and wing) and Q_{24} (tail and fin), while the generalised forces for modes involving the same or coplanar surfaces all agree. This suggests a possible error in the solution method of either [1] or [9] (as opposed to the post-processing to compute the generalised forces). The solution method in [1] has been checked in a number of ways to ensure consistency between the y and z directions, and for the correct sign of the generalised forces for some simple modes.

Results in Tables 5a and 5b show similar behaviour to that shown in Table 4. Here comparison is made between the present method and the results of [8], [9] and [11] for the T-tail configuration shown in Figure 1. The present program is set up so that the horizontal tail is in the plane $z = 0$ instead of $z = 1.2$. The mode shapes are adjusted accordingly to become

1. Fin Bending $y = (z + 1.2)^2$,
2. Fin Twist $y = (z + 1.2)(x - 0.875(z + 1.2) - 3.0)$,

and 3. Tail Roll $z = y$.

Again, there are significant differences between the codes for modes involving perpendicular surfaces, while the modes involving coplanar surfaces are in good agreement.

5. CONCLUSION

This paper serves two purposes. The first is to describe changes to the program SUPER presented in [1] resulting from the correction of programming errors and minor inconsistencies, and from alterations enabling the calculation of generalised forces. The second is to compare the generalised force results with those calculated by different methods for some standard test cases.

It is found that, in general, the results from the present method agree quite well with comparable codes, except that the present method tends to underestimate the magnitude of the forces by a small amount. However, there are some differences for off-diagonal modes involving perpendicular surfaces (i.e. tail and fin, wing and fin) which cannot fully be explained at present. In those cases, though, there is some scatter in the results of all methods. Careful testing of the present code has produced no evidence of internal inconsistency or error.

Future work with SUPER will involve computing generalised forces for realistic geometries such as the F111 (wing, tail and vertical fin, with the fuselage represented by horizontal and vertical surfaces).

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TABLES

TABLE 1

Wing and Horizontal Tail Interference
at $M = 1.2$ and $k = 0.0, 1.5$

	i,j	$k = 0.0$ Ref. 6	$k = 0.0$ Ref. 2	$k = 0.0$ Ref. 1	$k = 1.5$ Ref. 6	$k = 1.5$ Ref. 2	$k = 1.5$ Ref. 1
Q'_{ij}	1,1	-0.0672	-0.0680	-0.0661	-0.0931	-0.1071	-0.0991
	2,1	0.2868	0.2833	0.2774	0.4040	0.3714	0.3705
	3,1	-0.5037	-0.4940	-0.4829	-0.4149	-0.4038	-0.3937
	4,1	-0.2784	-0.2639	-0.2593	-0.2390	-0.2559	-0.2350
	1,2				-0.1491	-0.1401	-0.1389
	2,2				-0.3009	-0.3135	-0.2876
	3,2				-0.4632	-0.3798	-0.4515
	4,2				-0.3141	-0.2804	-0.3003
	1,3				0.0008	0.0079	0.0010
	2,3				0.0013	0.0117	0.0015
	3,3				-0.0982	-0.1255	-0.1001
	4,3				-0.1467	-0.1702	-0.1515
	1,4	0.0028	0.0044	0.0039	-0.0007	-0.0085	-0.0026
	2,4	0.0049	0.0073	0.0058	-0.0020	-0.0097	-0.0038
	3,4	0.7838	0.7519	0.7724	1.0239	0.9330	1.0025
	4,4	0.3163	0.2832	0.2952	0.5005	0.4345	0.4928
Q''_{ij}	1,1				0.2675	0.2331	0.2367
	2,1				0.4221	0.3957	0.3927
	3,1				0.3175	0.2514	0.3108
	4,1				0.2017	0.1919	0.1926
	1,2				0.0044	-0.0227	-0.0071
	2,2				0.2772	0.2401	0.2556
	3,2				0.0015	-0.0533	-0.0053
	4,2				-0.0046	-0.0359	-0.0133
	1,3				-0.0002	-0.0002	-0.0002
	2,3				-0.0003	-0.0019	-0.0004
	3,3				0.4828	0.4771	0.4757
	4,3				0.2911	0.2856	0.2872
	1,4				-0.0024	-0.0003	-0.0017
	2,4				-0.0038	0.0023	-0.0025
	3,4				0.5650	0.5816	0.5623
	4,4				0.6388	0.6372	0.6279

TABLE 2

Wing and Horizontal Tail Interference
at $M = 1.356$ and $k = 0.0, 1.5$

		$k = 0.0$			$k = 1.5$		
	i,j	Ref. 6	Ref. 7	Ref. 1	Ref. 6	Ref. 7	Ref. 1
Q'_{ij}	1,1		-0.0541	-0.0587	-0.0484	0.0041	-0.0552
	2,1		0.2910	0.2859	0.4637	0.4986	0.4226
	3,1		-0.5073	-0.4986	-0.3395	-0.4503	-0.3258
	4,1		-0.3218	-0.3024	-0.1742	-0.2507	-0.1671
	1,2				-0.1501	-0.1523	-0.1361
	2,2				-0.2831	-0.2694	-0.2623
	3,2				-0.4369	-0.4341	-0.4083
	4,2				-0.2882	-0.2941	-0.2693
Q''_{ij}	1,1				0.2766	0.2992	0.2461
	2,1				0.3933	0.4168	0.3705
	3,1				0.3261	0.3115	0.3021
	4,1				0.2083	0.2083	0.1925
	1,2				0.0120	0.0299	0.0063
	2,2				0.2329	0.2912	0.2667
	3,2				0.0160	-0.0144	0.0116
	4,2				0.0179	-0.0041	0.0132

TABLE 3a

Wing and Horizontal Tail Interference
at $M = 3.0$ and $k = 0.0$

	i,j	$k = 0.0$ Ref. 6	Ref. 7	Ref. 8	Ref. 10	Ref. 1
Q'_{ij}	1,1	-0.0226	-0.0208	-0.0187	-0.0046	-0.0233
	2,1	0.3035	0.3020	0.3287	0.3062	0.3049
	3,1	-0.2152	-0.2137	-0.1075	-0.2091	-0.2174
	4,1	-0.1550	-0.1516	-0.0843	-0.1476	-0.1396
	1,2					
	2,2					
	3,2					
	4,2					
	1,3					
	2,3					
	3,3					
	4,3					
	1,4					
	2,4					
	3,4	0.4665		0.4756	0.4635	0.4634
	4,4	0.2882		0.2904	0.2875	0.2669

TABLE 3b

Wing and Horizontal Tail Interference
at $M = 3.0$ and $k = 1.5$

	i,j	$k = 1.5$ Ref. 6	Ref. 7	Ref. 8	Ref. 10	Ref. 1
Q'_{ij}	1,1	0.0966	0.1002	0.0901	0.0771	0.0941
	2,1	0.3846	0.3740	0.3895	0.3616	0.3744
	3,1	-0.0394	-0.0463	-0.0695	-0.0492	-0.0527
	4,1	-0.0147	-0.0171	-0.0360	-0.0201	-0.0095
	1,2	-0.0700	-0.0720	-0.0819	-0.0688	-0.0648
	2,2	-0.0759	-0.0730	-0.0888	-0.0969	-0.0683
	3,2	-0.1531	-0.1477	-0.0400	-0.1541	-0.1434
	4,2	-0.1033	-0.0988	-0.0179	-0.1029	-0.0885
	1,3					
	2,3					
	3,3	0.0168		0.0140	-0.0094	0.0193
	4,3	0.0050		0.0032	-0.0137	0.0064
	1,4					
	2,4					
	3,4	0.4517		0.4541	0.4307	0.4449
	4,4	0.2965		0.2903	0.2680	0.2726
Q''_{ij}	1,1	0.1486	0.1463	0.1593	0.1449	0.1384
	2,1	0.0890	0.0890	0.1083	0.1189	0.0804
	3,1	0.0769	0.0696	0.0007	0.0761	0.0620
	4,1	0.0559	0.0517	0.0008	0.0552	0.0457
	1,2	0.0309	0.0327	0.0300	0.0319	0.0269
	2,2	0.2363	0.2335	0.2498	0.2309	0.2337
	3,2	0.0239	0.0160	-0.0003	0.0151	0.0075
	4,2	0.0197	0.0167	0.0030	0.0155	0.0164
	1,3					
	2,3					
	3,3	0.2560		0.2635	0.2552	0.2510
	4,3	0.1786		0.1820	0.1766	0.1657
	1,4					
	2,4					
	3,4	0.1632		0.1820	0.1945	0.1577
	4,4	0.2188		0.2300	0.2327	0.2046

TABLE 4

Wing, Tail and Fin Interference
at $M = 3.0$ and $k = 0.0, 1.5$

	i,j	$k = 0.0$ Ref. 8	$k = 0.0$ Ref. 9	$k = 0.0$ Ref. 1	$k = 1.5$ Ref. 8	$k = 1.5$ Ref. 9	$k = 1.5$ Ref. 1
Q'_{ij}	1,1	-0.0202	-0.0285	-0.0233	0.0839	0.0918	0.0941
	2,1	-0.1333	-0.1360	-0.1288	-0.1779	0.0073	-0.0189
	3,1	-0.0980	-0.1000	0.0434	0.0492	0.0490	-0.0192
	4,1	-0.0460	-0.0459	0.0223	0.0240	0.0253	-0.0115
	1,2						
	2,2	0.3420	0.3366	0.2919	0.3137	0.3096	0.2811
	3,2	-0.0176	-0.0183	0.0112	0.0042	0.0058	-0.0029
	4,2	-0.0414	-0.0422	0.0261	-0.0059	-0.0003	0.0026
	1,3						
	2,3				-0.0046	-0.0044	0.0029
	3,3				-0.0420	-0.0400	-0.0405
	4,3				-0.0217	-0.0215	-0.0209
	1,4						
	2,4	-0.0144	-0.0137	0.0089	-0.0017	-0.0008	0.0006
	3,4	0.3400	0.3396	0.3113	0.3314	0.3345	0.3095
	4,4	0.0545	0.0534	0.0412	0.0551	0.0564	0.0477
Q''_{ij}	1,1				0.1641	0.1559	0.1384
	2,1				0.1444	0.0409	0.0429
	3,1				0.0066	0.0048	0.0009
	4,1				0.0185	0.0098	-0.0033
	1,2						
	2,2				0.2160	0.2127	0.1981
	3,2				0.0084	0.0087	-0.0055
	4,2				0.0170	0.0179	-0.0113
	1,3						
	2,3				-0.0006	-0.0005	0.0003
	3,3				0.2918	0.2930	0.2640
	4,3				0.0361	0.0364	0.0277
	1,4						
	2,4				0.0059	0.0057	-0.0038
	3,4				0.0780	0.0762	0.0675
	4,4				0.0711	0.0703	0.0667

TABLE 5a

Tail and Fin Interference
at $M = 1.6$, $Z = 1.2$ and $k = 0.0$

	i,j	$k = 0.0$ Ref. 8	Ref. 9	Ref. 11	Ref. 1
Q'_{ij}	1,1				
	2,1				
	3,1				
	1,2	0.8089	0.7948		0.8062
	2,2	0.0970	0.0807		0.0819
	3,2	0.2258	0.1828		-0.4471
	1,3				
	2,3				
	3,3				

TABLE 5b

Tail and Fin Interference
at $M = 1.6$, $Z = 1.2$ and $k = 1.5$

		$k = 1.5$			
	i,j	Ref. 8	Ref. 9	Ref. 11	Ref. 1
Q'_{ij}	1,1	-0.0125	0.0093	0.0236	0.0298
	2,1	-0.0605	-0.0553	-0.0516	-0.0509
	3,1	0.0560	0.0473	0.1931	-0.3310
	1,2	0.6516	0.6926	0.6864	0.6879
	2,2	0.1031	0.1158	0.1250	0.1159
	3,2	-0.1359	-0.0458	0.0745	-0.0492
	1,3	0.0370	0.0450	0.0676	-0.0322
	2,3	0.1795	0.0211	0.0277	-0.0132
	3,3	0.0025	0.0192	0.0622	0.0266
Q''_{ij}	1,1	0.5200	0.5457	0.5466	0.5444
	2,1	0.0449	0.0462	0.0620	0.0462
	3,1	0.1209	-0.0627	0.0471	-0.0373
	1,2	0.1430	0.1086	0.1295	0.0933
	2,2	0.1643	0.1552	0.1518	0.1497
	3,2	0.0047	-0.0071	-0.0952	0.2091
	1,3	0.0527	0.0561	0.0341	-0.0268
	2,3	0.0166	0.0157	0.0074	-0.0076
	3,3	0.4457	0.4783	0.4309	0.4188

FIGURES

	x	y	z
a	0	0	0
b	2.25	0	0
c	2.75	1.00	0
d	3.70	1.00	0
e	2.70	0	0
f	4.00	0	0
g	3.90	1.00	0
h	4.25	1.00	0
e′	3.10	0	0.60
f′	4.40	0	0.60
g′	4.30	1.00	0.60
h′	4.65	1.00	0.60
e″	3.56	0	1.20
f″	4.85	0	1.20
g″	4.75	1.00	1.20
h″	5.10	1.00	1.20
e‴	2.70	0	0
f‴	4.00	0	0
g‴	3.90	1.00	0.50
h‴	4.25	1.00	0.50
i	2.50	0	0
j	4.20	0	0
k	3.70	0	1.20
ℓ	4.60	0	1.20

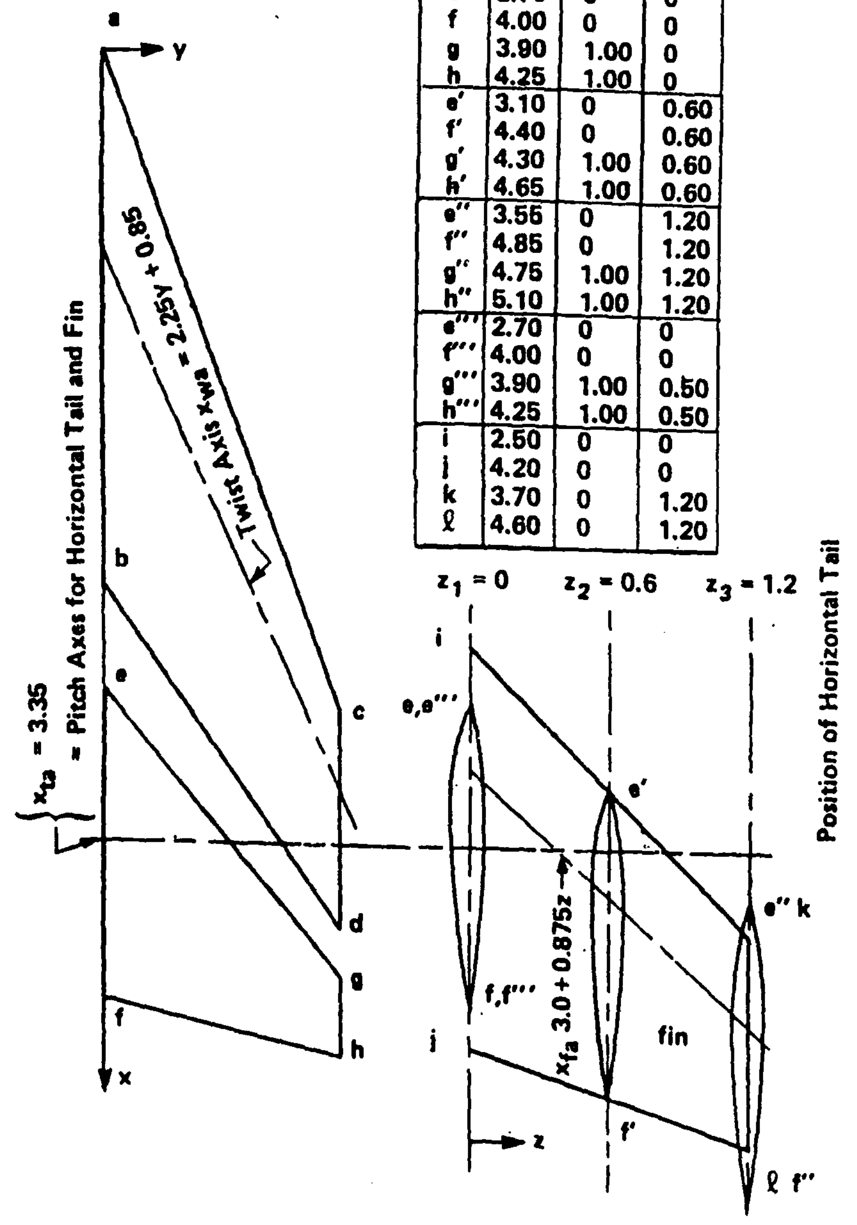

Figure 1. *AGARD horizontal wing, tail and vertical fin interference configuration*

APPENDIX 1 – LISTING OF MODE SHAPE SUBROUTINES

```
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      REAL FUNCTION WL(Y)
      WL=2.75*Y
      RETURN
      ENTRY WT(Y)
      WT=2.25+1.45*Y
      RETURN
      ENTRY TL(Y)
      TL=2.7+1.2*Y
      RETURN
      ENTRY TT(Y)
      TT=4.0+0.25*Y
      RETURN
      ENTRY FL(Z)
      FL=2.5+Z
      RETURN
      ENTRY FT(Z)
      FT=4.2+Z/3.0
      RETURN
      END
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      SUBROUTINE WING(X,Y,IP,H1,H2,IER)
      IER=0
      GO TO (1,2,3,4,5) IP
      IER=1
      RETURN
 1    CONTINUE
      H1=-1.0
      H2=-1.0
      RETURN
 2    CONTINUE
      H1=Y*(X-2.25*ABS(Y)-0.85)
      H2=Y
      RETURN
 3    CONTINUE
      H1=0.0
      H2=0.0
      RETURN
 4    CONTINUE
      H1=0.0
      H2=0.0
      RETURN
 5    CONTINUE
      H1=0.0
      H2=0.0
      RETURN
      END
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
```

```
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      SUBROUTINE TAIL(X,Y,IP,H1,H2,IER)
      IER=0
      GO TO (1,2,3,4,5) IP
      IER=1
      RETURN
 1    CONTINUE
      H1=-1.0
      H2=-1.0
      RETURN
 2    CONTINUE
      H1=0.0
      H2=0.0
      RETURN
 3    CONTINUE
      H1=(X-3.35)*SIGN(1.0,Y)
      H2=SIGN(1.0,Y)
      RETURN
 4    CONTINUE
      H1=0.0
      H2=0.0
      RETURN
 5    CONTINUE
      H1=0.0
      H2=0.0
      RETURN
      END
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      SUBROUTINE FIN(X,Z,IP,H1,H2,IER)
      IER=0
      GO TO (1,2,3,4,5) IP
      IER=1
      RETURN
 1    CONTINUE
      H1=-1.0
      H2=-1.0
      RETURN
 2    CONTINUE
      H1=0.0
      H2=0.0
      RETURN
 3    CONTINUE
      H1=0.0
      H2=0.0
      RETURN
 4    CONTINUE
      H1=Z*Z
      H2=0.0
      RETURN
 5    CONTINUE
      H1=Z*(X-0.875*Z-3.0)
      H2=Z
      RETURN
      END
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
```

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This paper describes changes to the computer program "SUPER", which correct errors identified in the previous version of the program, and enable the calculation of generalised forces. Tables of generalised forces, calculated using "SUPER" and other programs, are presented for a standard AGARD configuration.

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